CLMPTO

02/10/06

1. A computerized method for estimating scattering of electromagnetic radiation from a surface, the method comprising:

providing a distribution expression that includes a first integral over a source solid angle, a second integral over a sample area, a third integral over detector solid angle, and an integrand that includes a differential-scattering profile;

approximating the first and second integrals to be the second integral, wherein the source electromagnetic radiation is approximated to be collimated;

approximating the second and third integral to be the third integral, wherein a detector for detecting the electromagnetic radiation scattered from the surface is approximated to be a point detector;

transforming the coordinates of the third integral over detector solid angle to first and second dimensions in cosine space to form a fourth integral, wherein the surface is approximated to be shift invariant;

integrating over the first dimension of the fourth integral;

differentiating the fourth integral with respect to the second dimension to generate the differential-scattering profile; and

generating an optical system design based on the differential-scattering profile.

2. The method of claim 1, wherein the distribution expression includes a bidirectional reflectance distribution function (BRDF).

3. The method of claim 2, wherein the bidirectional reflectance distribution function may be represented by the equation:

$$\mathrm{BRDF} = \frac{1}{P_i}\frac{1}{\Omega_i}\int_{\Omega i}\int_{Area}\int_{\Omega d}\frac{d^2P_i}{d\Omega_i dA}\frac{dp_d(\Omega_i,\Omega_d,A)}{d\Omega_d}\,d\Omega_i\,dA\,d\Omega_d,$$

wherein:

the integral with respect to $d\Omega_i$ is the first integral,

the integral with respect to dA is the second integral,

the integral with respect to $d\Omega_d$ is the third integral,

the expression $\frac{dp_d(\Omega_i,\Omega_d,A)}{d\Omega_d}$ is the differential scattering profile,

and

P_i is incident power of the electromagnetic radiation.

4. The method of claim 1, further comprising generating an empirical-differential-scattering profile from measured data of electromagnetic radiation scattering from a physical surface corresponding to the surface, a difference of the empirical-differential-scattering profile and the differential-scattering profile being less than about ten percent.

5. The method of claim 1, wherein the differential-scattering profile is a continuous solution representing an algebraic model of specular scattering and non-specular scattering of the electromagnetic radiation from the surface.

6. The method of claim 1, wherein lines of constant-scattering intensity are co-centric circles in cosine space.

7. The method of claim 6, wherein the first dimension in cosine space is a radial dimension perpendicular to the co-centric circles.

8. The method of claim 7, wherein the second dimension is a circular dimension following the co-centric circles.

9. The method of claim 6, wherein the first dimension is a circular dimension following the co-centric circles.

10. The method of claim 9, wherein the second dimension in cosine space is a radial dimension perpendicular to the co-centric circles.

11. The method of claim 6, wherein the co-centric circles are lines of constant $|\beta - \beta_0|$.

12. The method of claim 11, wherein $|\beta - \beta_0| = (\sin^2\theta_i + \sin^2\theta_d - 2\sin^2\theta_i \sin^2\theta_d \cos\Delta\varphi)^{1/2}$.

13. The method of claim 12, further comprising estimating $|\beta - \beta_0| = \theta_i + \theta_d$ for relatively small angle approximations of θ_i and for $\Delta\varphi$ being approximately zero.

14. The method of claim 1, wherein the fourth integral may be represented by the expression:

$$\text{BRDF} = \int_{D'} \frac{dp(|\beta - \beta_0|)}{d\Omega} \sqrt{k_1} \left| \frac{\partial(\theta,\phi)}{\partial(k_1 k_2)} \right| dk_1 dk_2 ,$$

wherein:

k_1 is a coordinate in cosine space and follows lines of constant $|\beta - \beta_0|$:

k_2 is another coordinate in cosine space that is perpendicular to lines of constant $|\beta - \beta_0|$; and

$$|\beta - \beta_0| = \sqrt{\sin^2\theta + \sin^2\theta_0 - 2\sin\theta\sin\theta_0} \; .$$

15. The method of claim 1, wherein the differentiating step includes deconvolving the fourth integral.

16. The method of claim 1, wherein the step of approximating the first and second integrals to be the second integral includes approximating a one-to-one correspondence between a differential element of the source electromagnetic radiation and a differential surface area of the surface.

17. The method of claim 1, wherein the step of approximating the second and third integral to be the third integral includes approximating that electromagnetic scattered from a differential surface area sources is incident on the point detector.

18. The method of claim 1, further comprising using the differential-scattering profile to reduce scattering in the optical system design.

19. The method of claim 1, further comprising using the differential-scattering profile to compensate for scattering in the optical system design.

20. The method of claim 1, wherein the optical system design includes a design for computer generated graphic.

21. A computerized method for estimating scattering of electromagnetic radiation from a surface, the method comprising:

providing a distribution expression that includes a first integral over a source solid angle, a second integral over a sample area, a third integral over detector solid angle, and an integrand that includes a differential-scattering profile;

approximating the first and second integrals to be the second integral, wherein source electromagnetic radiation is approximated to be collimated;

approximating third integral to be one based on detecting the electromagnetic radiation scattered from the surface at an imaging detector;

transforming the coordinates of the second integral over the sample area to first and second dimensions in cosine space to form a fourth integral, wherein the surface is approximated to be shift invariant;

integrating over the first dimension of the fourth integral;

differentiating the fourth integral with respect to the second dimension to generate the differential-scattering profile; and

generating an optical system design based on the differential-scattering profile.

22. The method of claim 21, further comprising implementing the differential-scattering profile to reduce scattering in the optical system design.

23. The method of claim 21, further comprising using the differential-scattering profile to compensate for scattering in the optical system design.

24. The method of claim 21, further comprising using the differential-scattering profile to simulate scattering in a computer generated graphic.

25. The method of claim 24, wherein the optical system design includes the computer generated graphic.

26. The method of claim 21, further comprising implementing the differential-scattering profile to simulate scattering from a physical surface.

27. An optical system comprising:

a collimated beam of electromagnetic radiation configured to illuminate a sample surface, the sample surface being shift invariant;

an imaging detector configured to collect electromagnetic radiation scattered from the sample surface, the imaging detector configured to collect the scattered

electromagnetic radiation at a plurality of scattering angels to generate a scattering profile; and

a computer device configured to generate an estimated-differential-scattering profile and compare the scattering profile and the estimated-differential-scattering profile to generate an optical system design, wherein the estimated-differential-scattering profile is a continuous solution of an differential model of spectral scattering and non-spectral scattering derived from a deconvolution of a bidirectional reflectance distribution function (BRDF).

28. The optical system of claim 27, wherein a difference between the scattering profile and the estimated-differential-scattering profile is less than or equal to about ten percent.

Cancelled claim 29

30. The optical system of claim 29, wherein the estimated-differential-scattering profile is configured to be used to reduce scattering in the optical system design.

31. The optical system of claim 29, wherein the estimated-differential-scattering profile is configured to be used to compensate for scattering in the optical system design.

32. The optical system of claim 29, wherein the estimated-differential-scattering profile is configured to be used to simulate scattering in a computer generated graphic.

33. The optical system of claim 24, wherein the optical system design includes a computer generated graphic.